Marine ecosystems and fish stocks under climate variability and change

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ICES ASC 2006, Maastricht, 21 September 2006





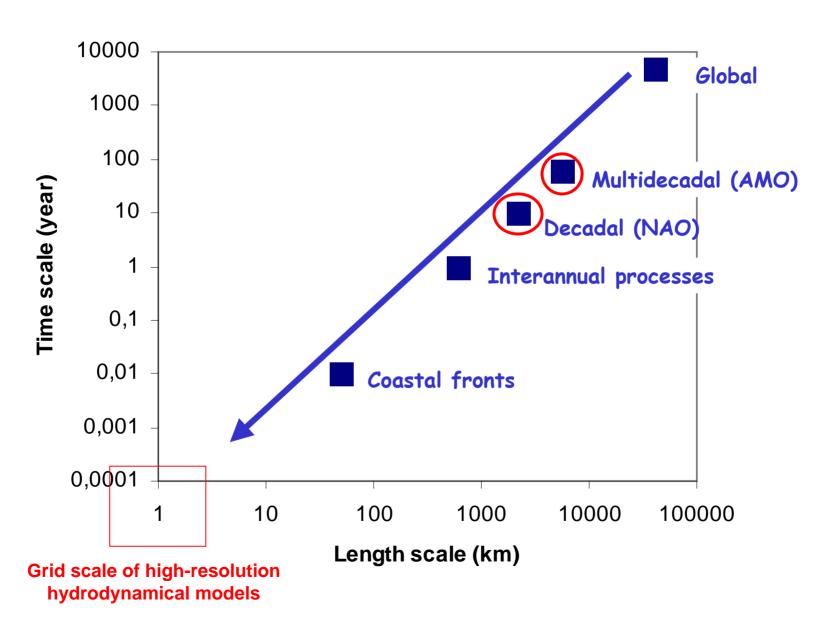


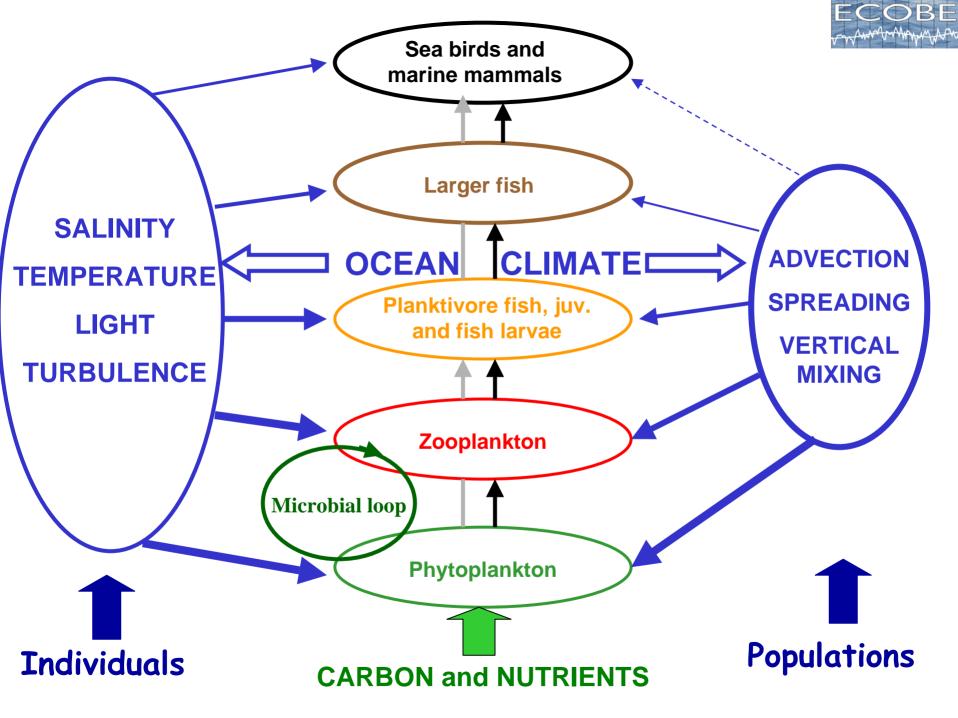
- The spectrum of climate variability
- Interannual fluctuations
- Decadal-scale oscillations (North Atlantic Oscillation)
- Multidecdal-scale oscillations (Atlantic Multidecadal Oscillation)
- Climate change

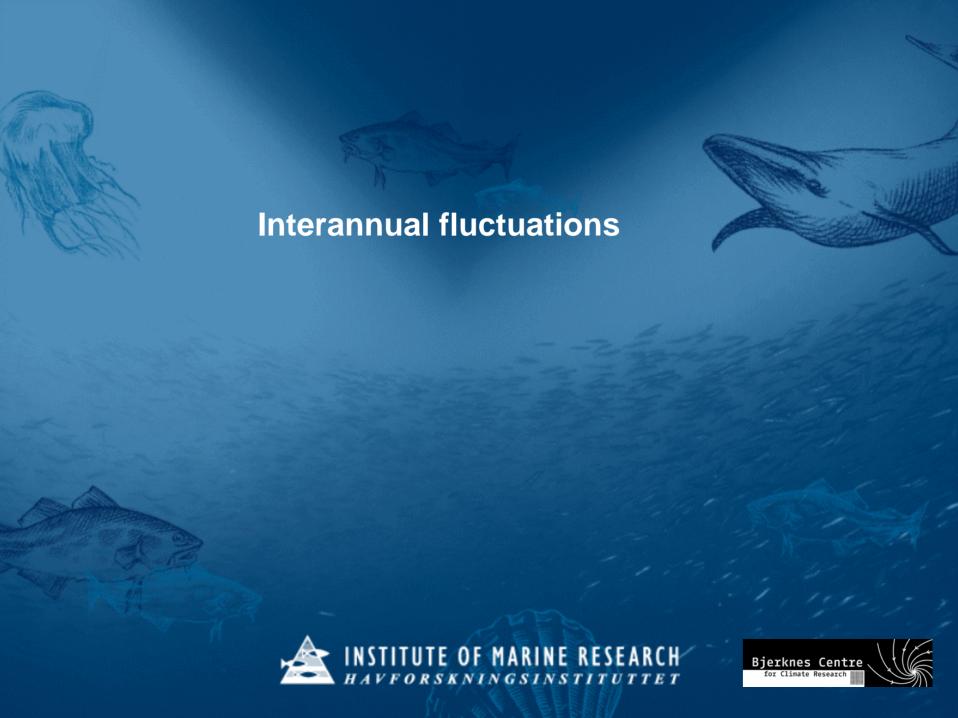




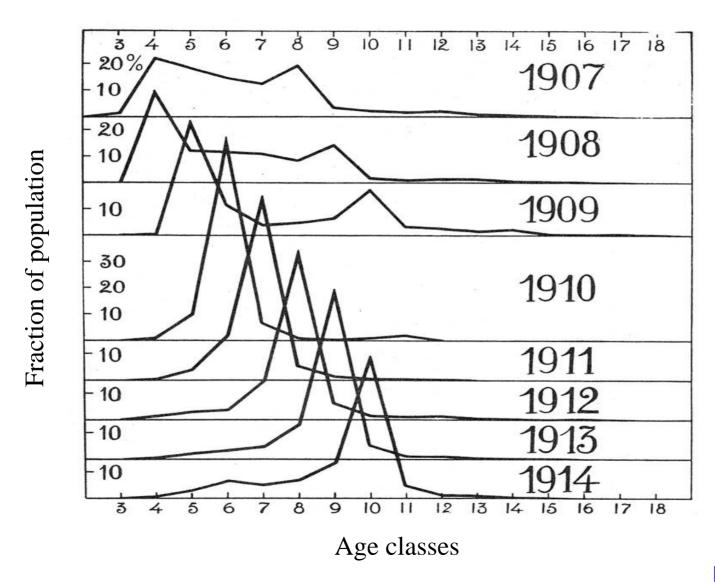
Spatio-temporal scales the ocean physics



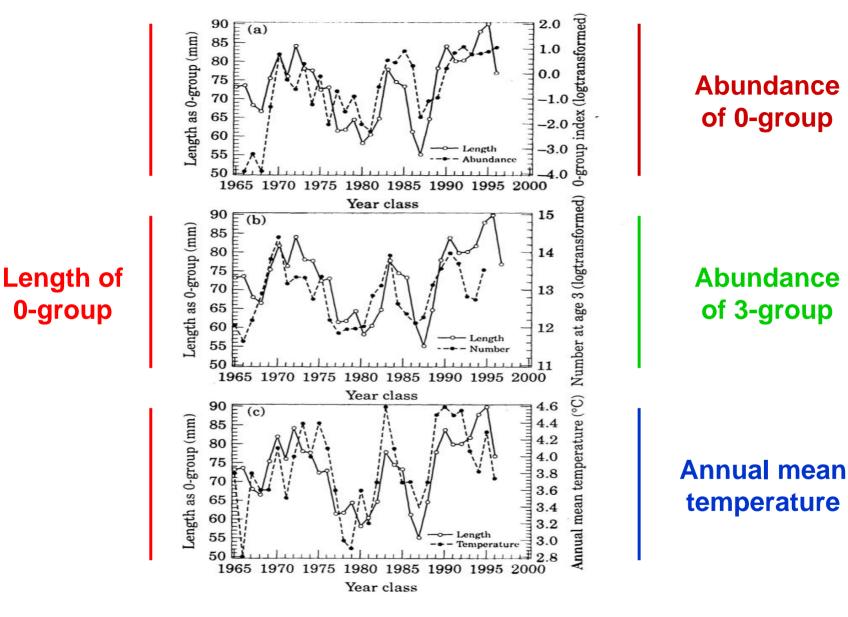




Age structure of the Atlanto-scandian herring during the years 1907 – 1914 with the outstanding 1904 year class

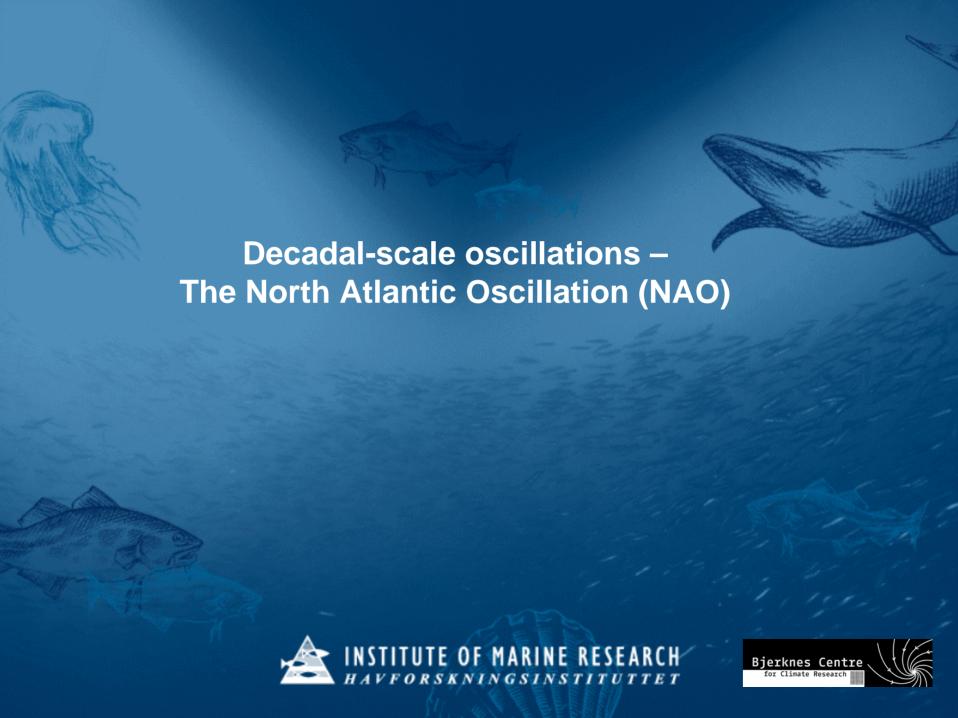


Barents Sea cod



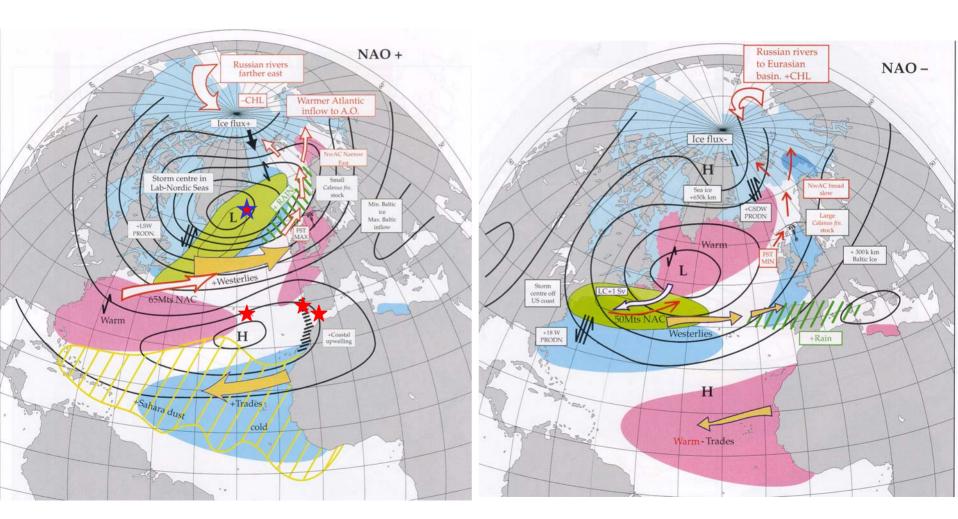
0-group

Ottersen and Loeng (2000)

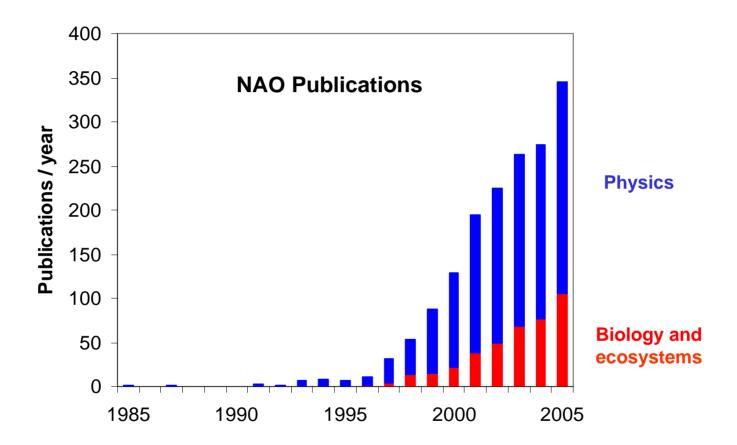


The North Atlantic Oscillation (NAO) Index:

The difference of the normalized sea level pressure between the Azores/Lisbon/Gibraltar and Iceland.



Hurrell and Dickson (2004) In: Marine ecosystems and Climate Variations (Stenseth et al. eds.)



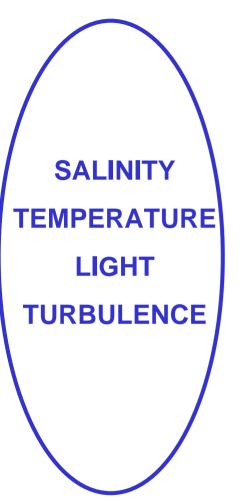
Effects of NAO

- Trees (Darrigo et al. 1993)
- Marine fish (Wainright et al. 1993)
- Marine zooplankton (Fromentin and Planque 1996)
- Marine phytoplankton (Lindahl et al. 1998)
- Aquatic zooplankton (Straile and Geller 1998)
- Terrestrial mammals (Post et al. 1999)
- Aquatic phytoplankton (Straile and Adrian 2000)
- Marine birds (Thompson and Ollason 2001)
- Birds (Moller 2002)
- Marine mammals (Ferguson et al. 2005)
- Cod in the Barents and Labrador Seas and the see saw in temperature (Ishevskii 1964)





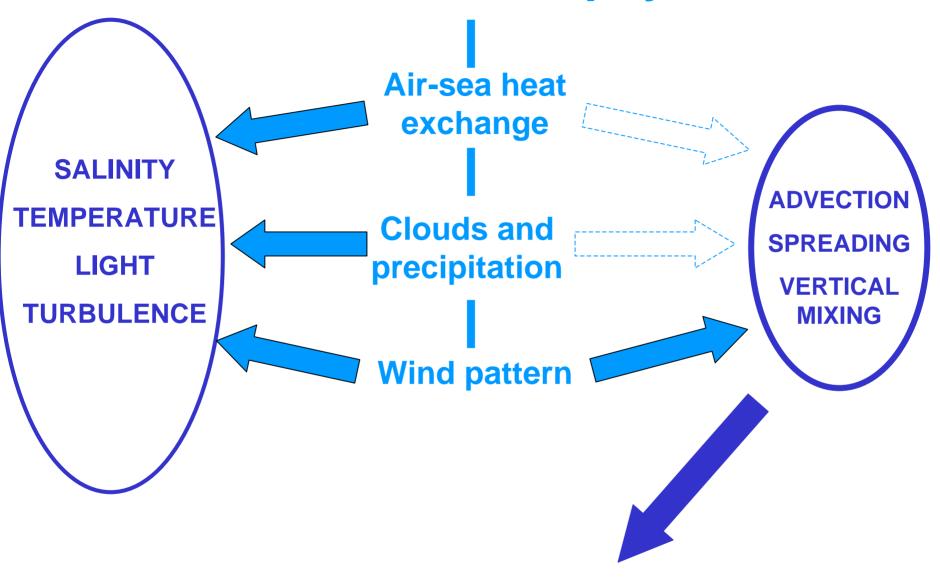
NAO Effects on physics



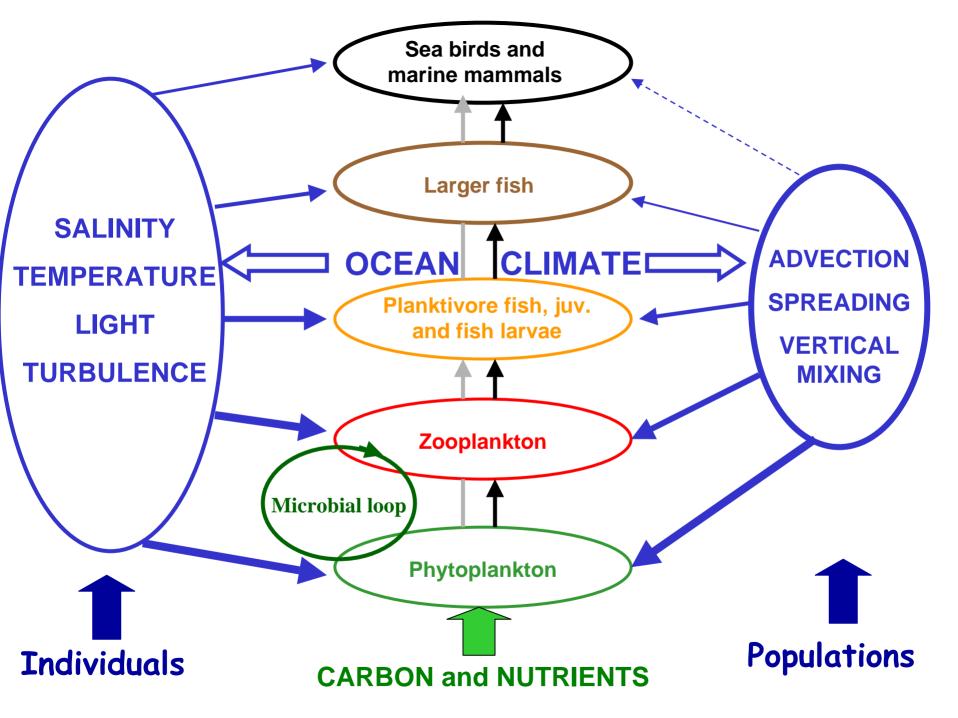
Air-sea heat exchange Clouds and precipitation Wind pattern



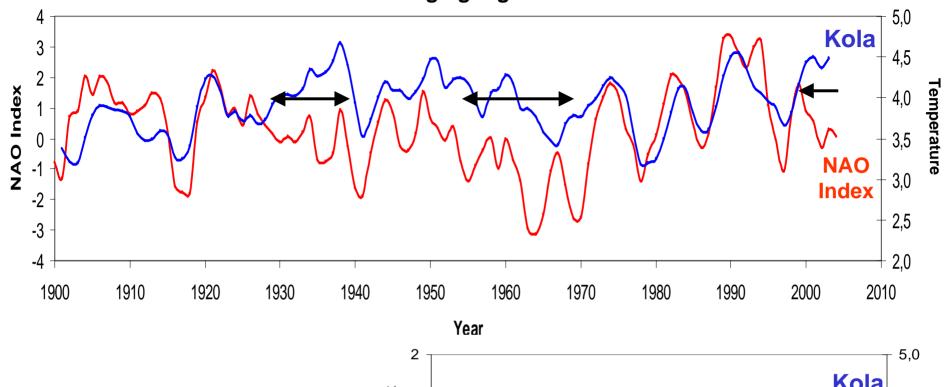
NAO Effects on physics

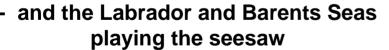


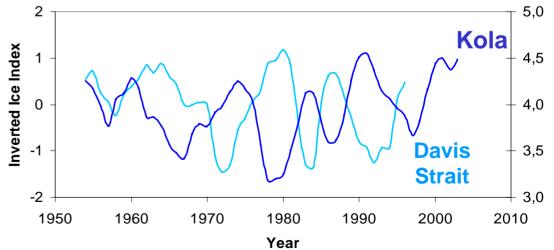
CARBON and NUTRIENTS



Strong decadal-scale signals makes the NAO and Barents Sea ocean climate swinging together

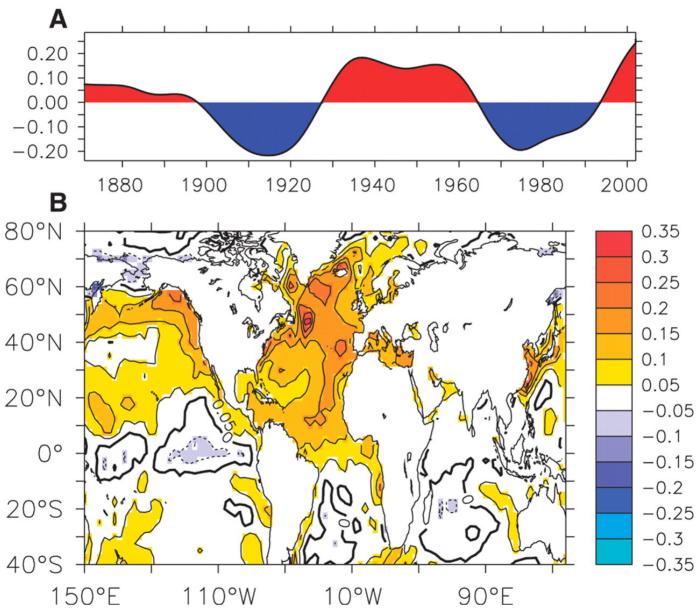






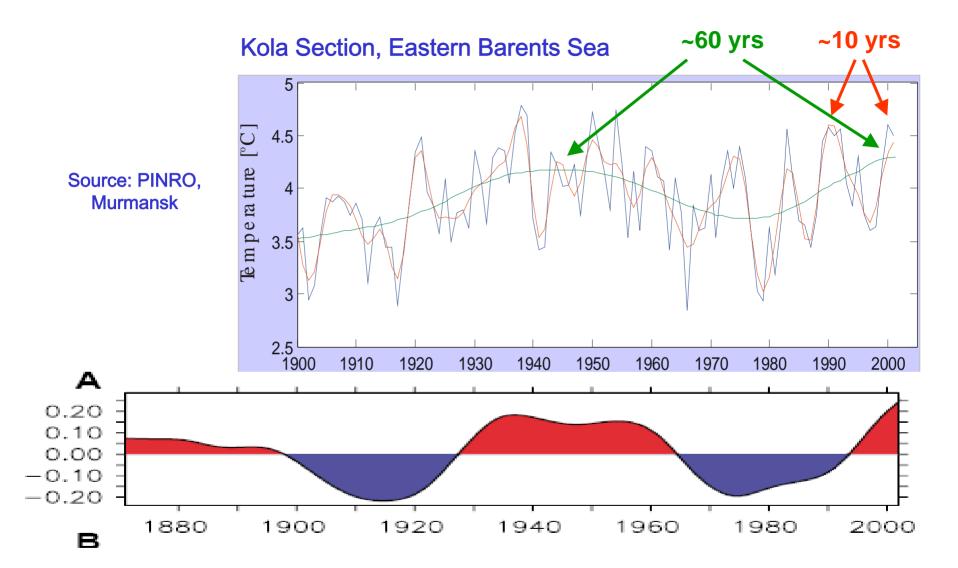


Atlantic Multidecadal Oscillation (AMO) during 1873-2000

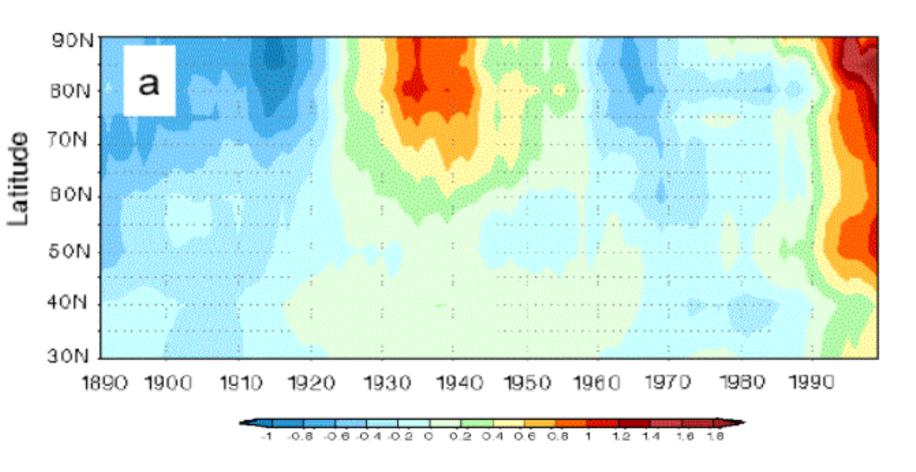




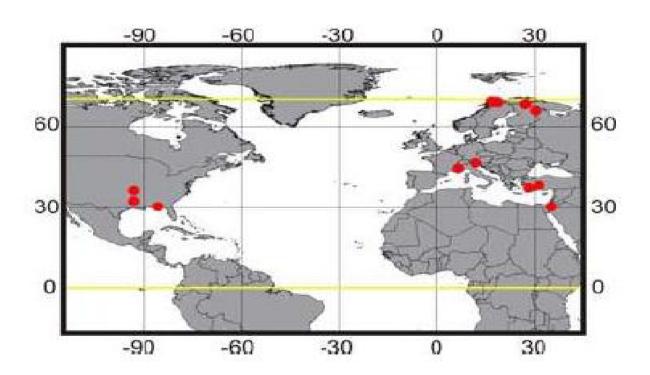
Sutton and Hodson (2005)

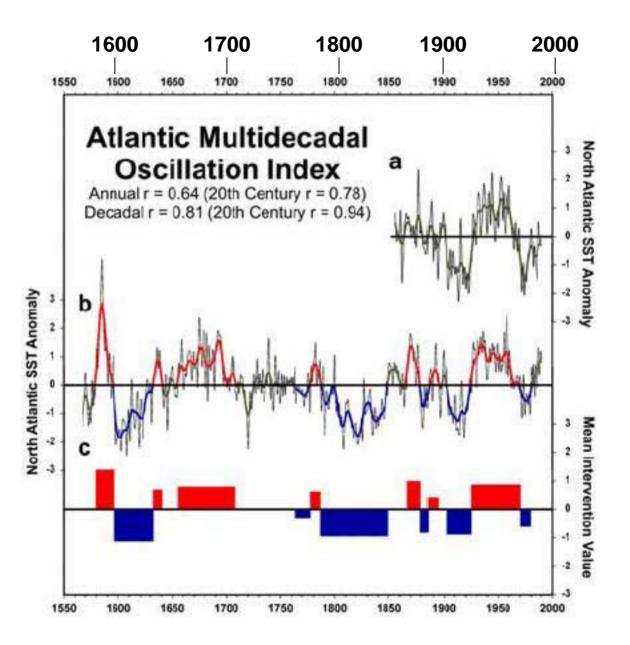


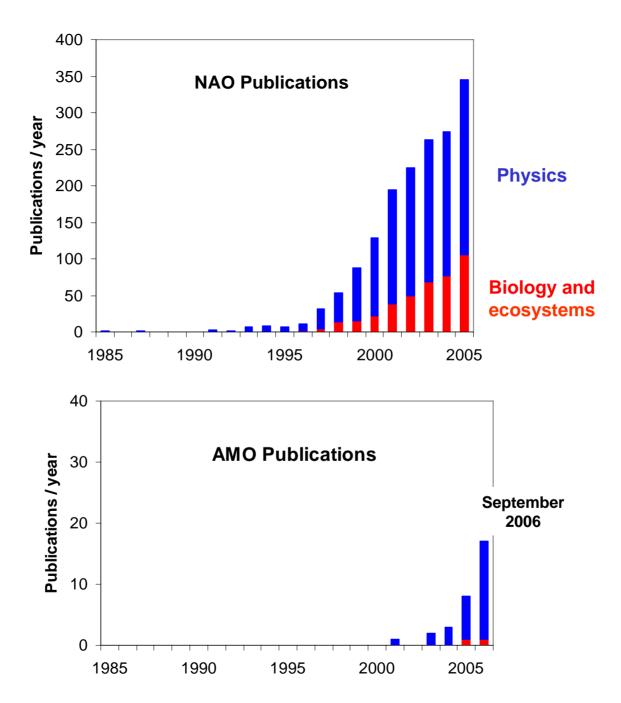
The AMO amplitude decrease towards Equator



Atlantic Multidecadal Oscillations (AMO) in the past - sample sites for tree ring analysis







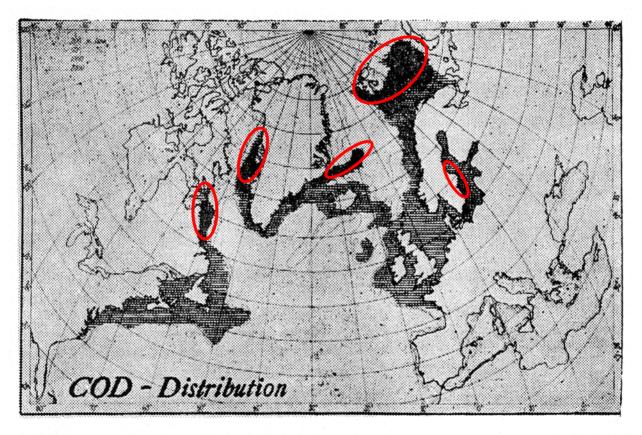


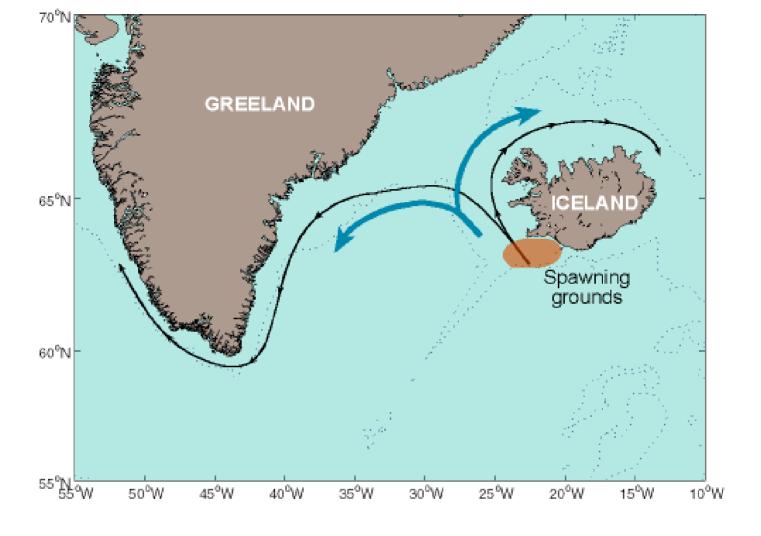
Fig. 1. Rough sketch of distribution of cod in the North Atlantic. Double hatching indicates areas where density of cod approximately has increased in recent time.

Some examples on effects of multidecadal climate oscillations

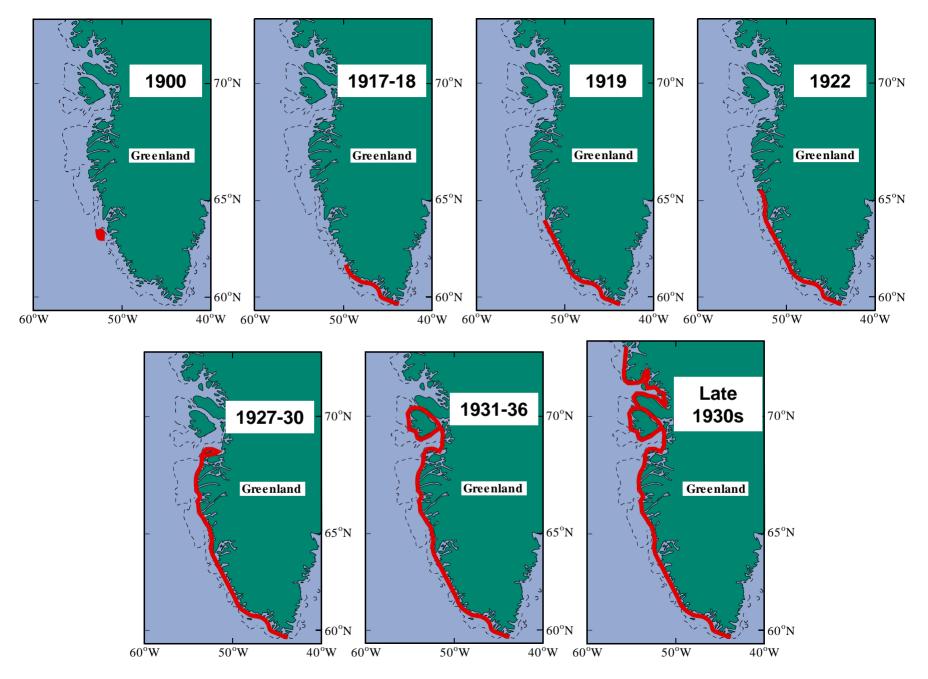
- The Greenland Sea cod
- The Norwegian spring-spawning herring
- The spawning sites of Arcto-Norwegian cod
- The decline in the North Sea and the mechanistic link between Arcto-Norwegian cod and North Sea cod







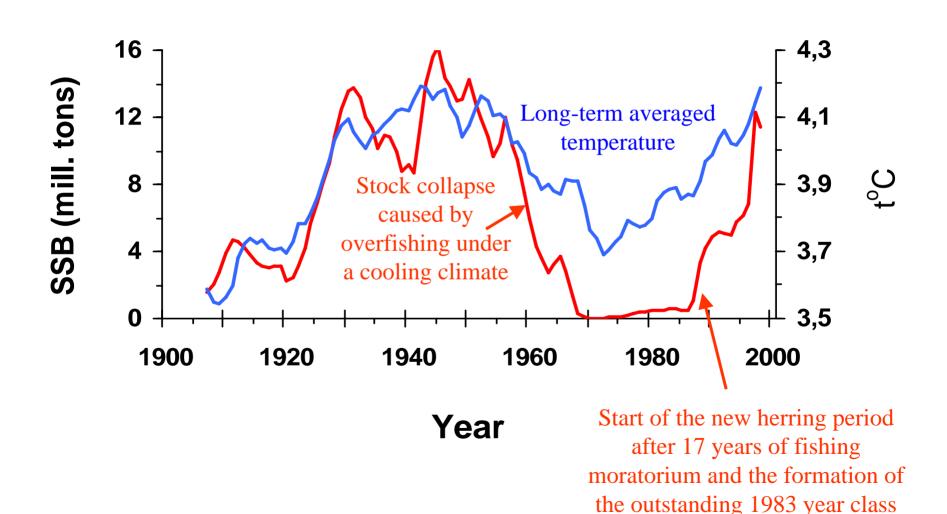
Some years around 1920 the ocean climate conditions were favourable for transport of cod larvae and juveniles from Iceland to Greenland

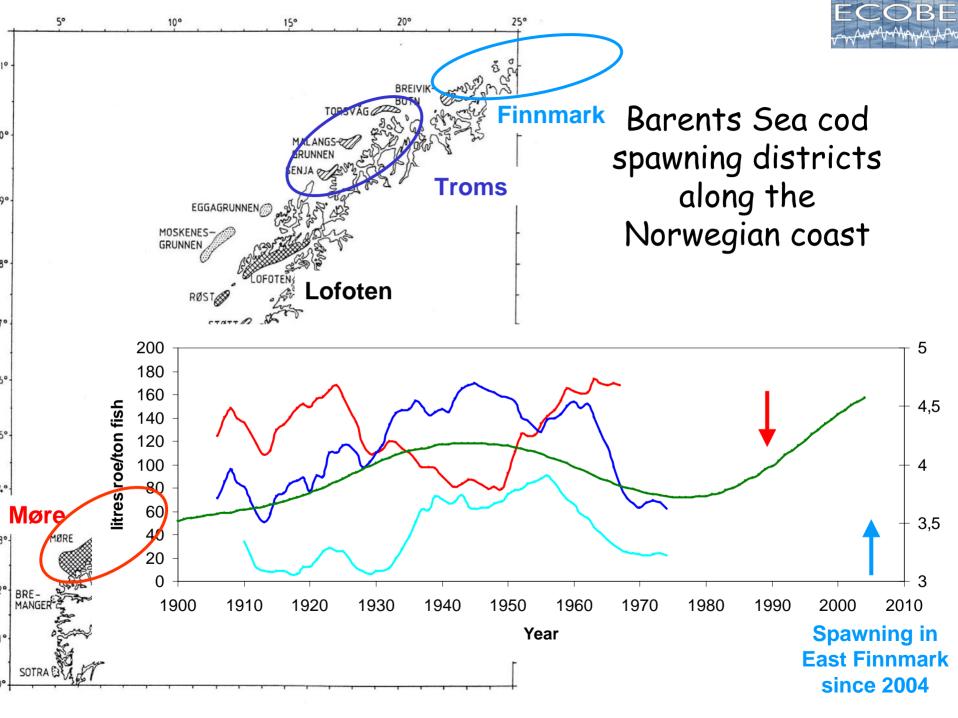


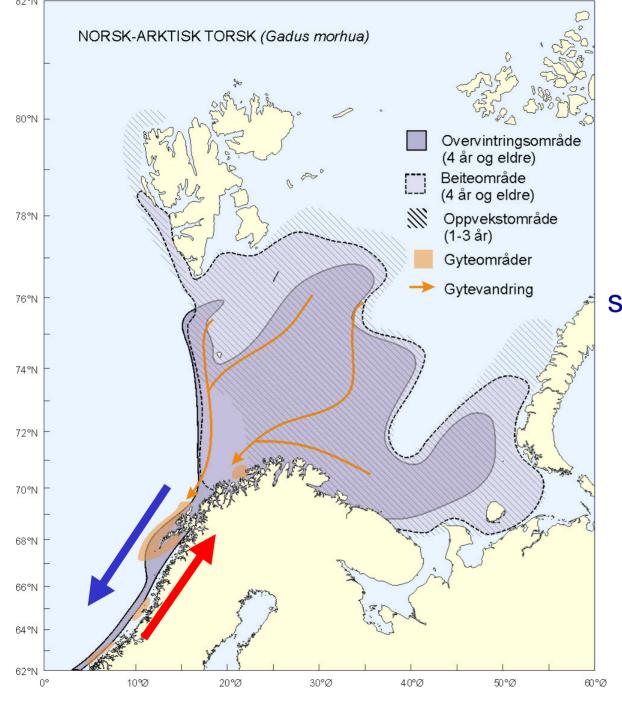
Compiled by Drinkwater (2006) after Hansen (1940)

Spawning stock biomass (SSB) of Norwegian spring-spawning herring and the longterm-averaged temperature (the AMO signal)

(Toresen og Østvedt 2000)









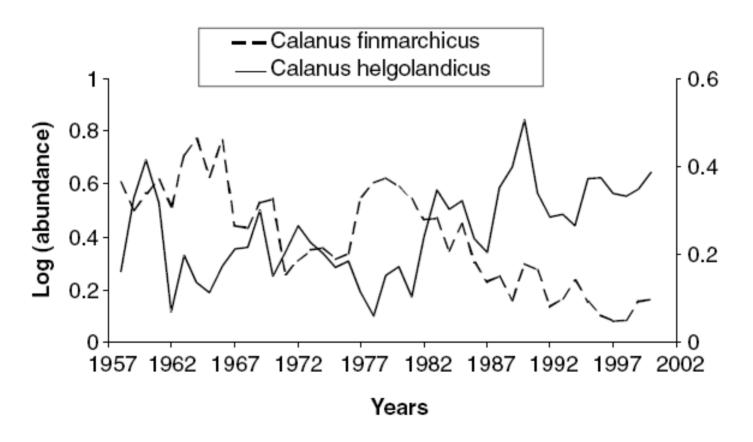
Ecosystems effects:

The spawning intensity along the spawning areas of the Barents Sea cod is influenced by interdecadal climate variations

Sundby and Nakken (2005)

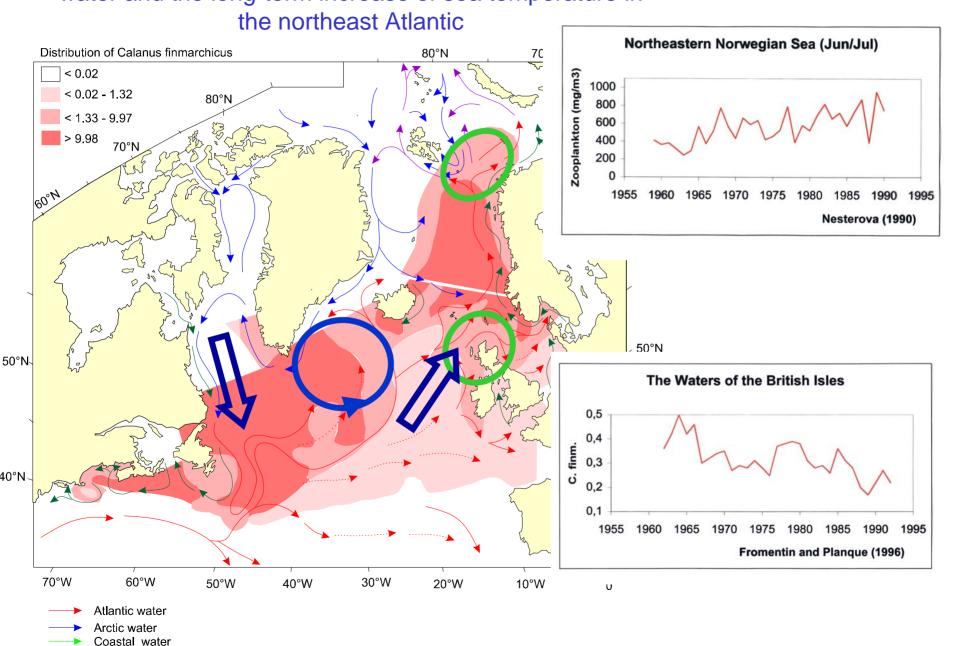


Figure 2. Graphs of the log abundance of C. *finmarchicus* (solid line) and C. *helgolandicus* (dashed line) averaged for the North Sea over the period 1958–2000.



The combined effects of increased influx of Atlantic water and the long-term increase of sea temperature in





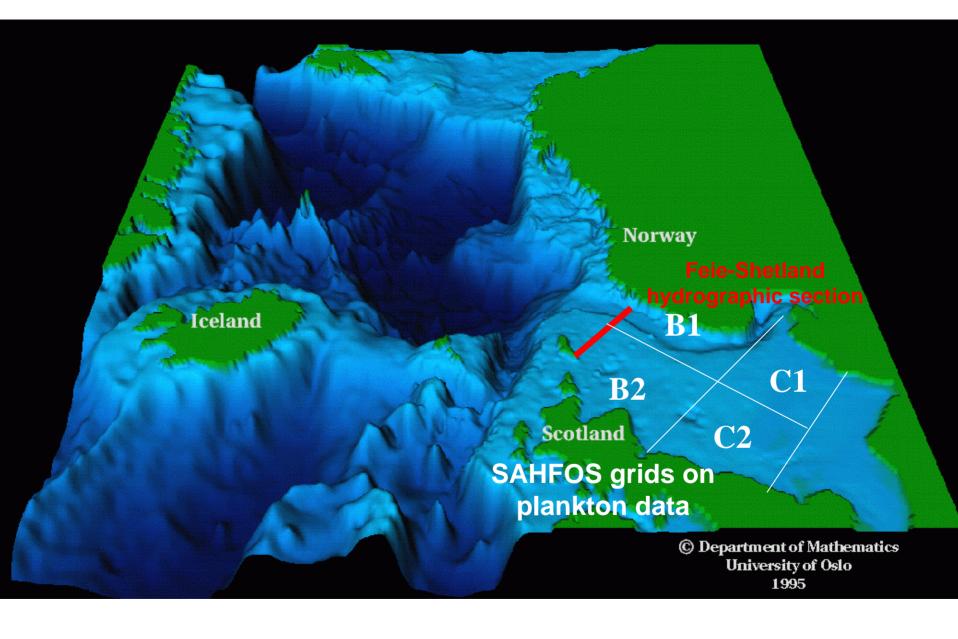


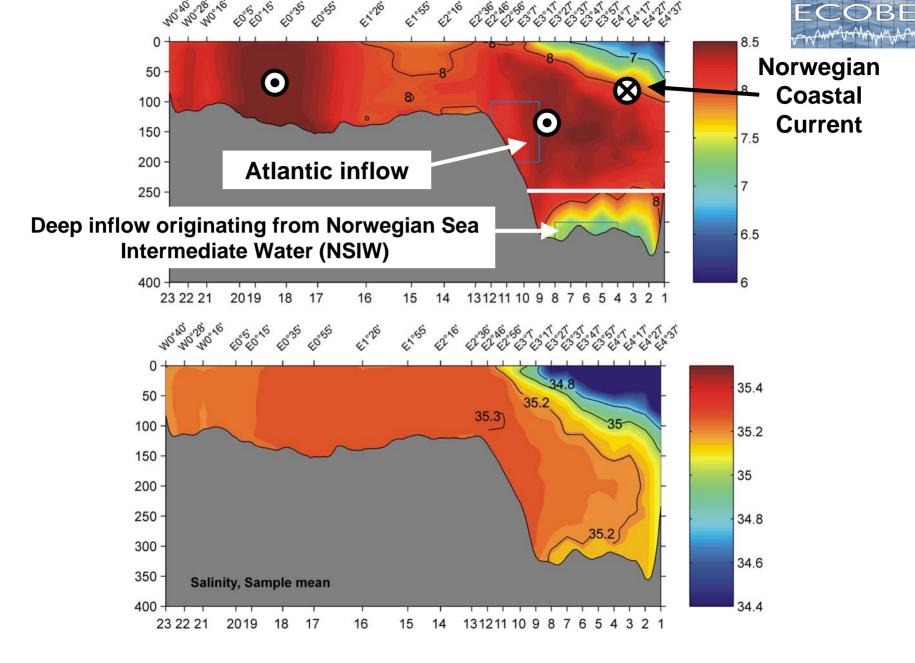
The continuity equation for plankton:

 $\partial P/\partial t = Diffusion - Advection + Plankton motion + Production - Mortality$



The advection term becomes particularly important for plankton of limited motility and long life cycle, e.g. copepods



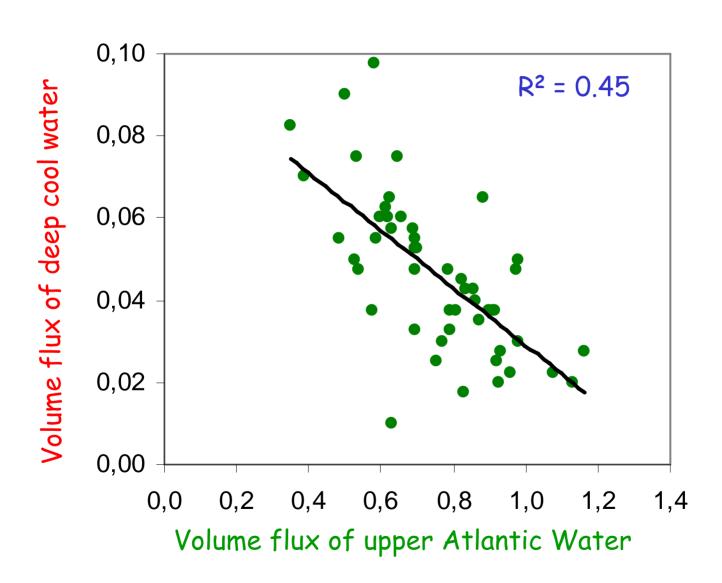


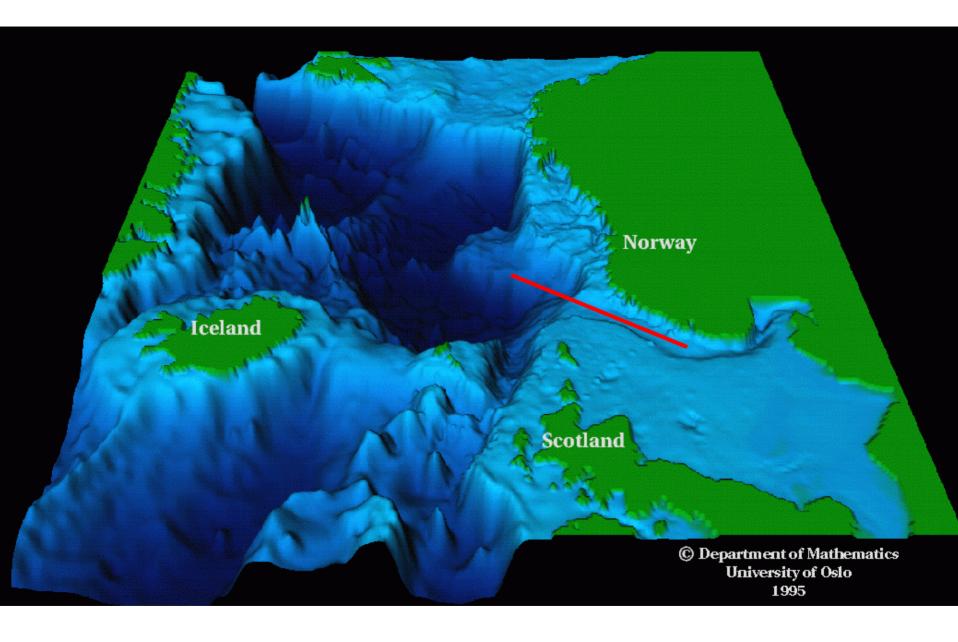
FEIE - SHETLAND section.1980-1999, Week 2-6.

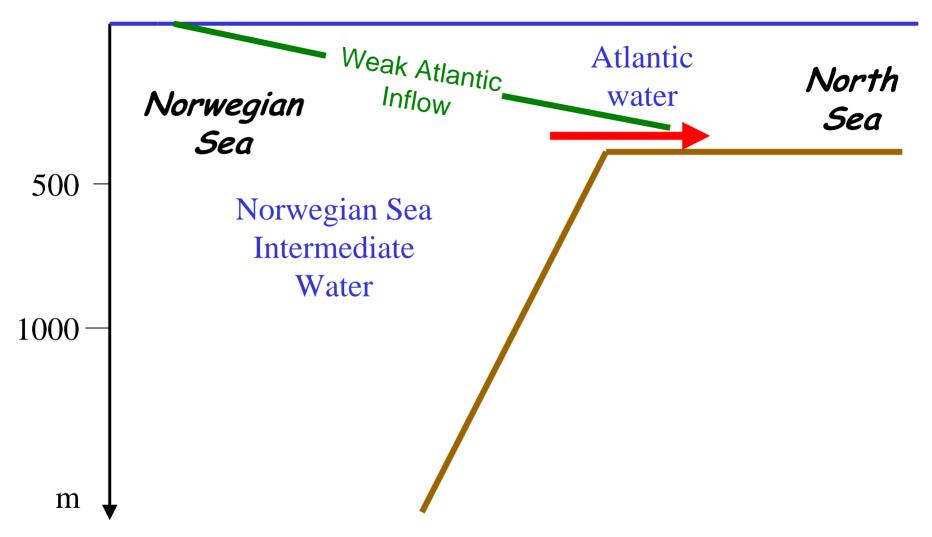
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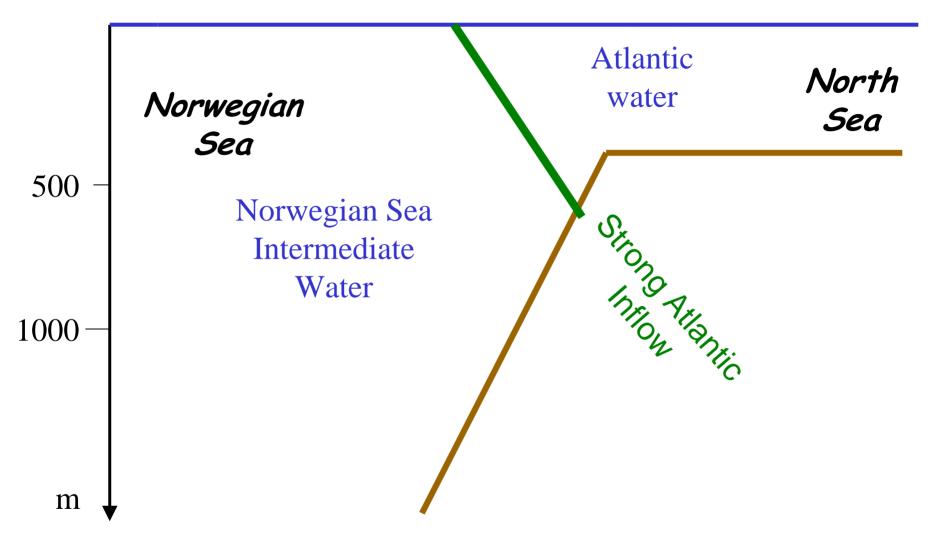


Inflow through the Norwegian Trench into the North Sea





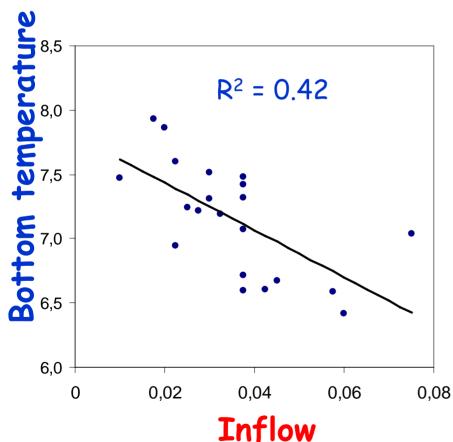






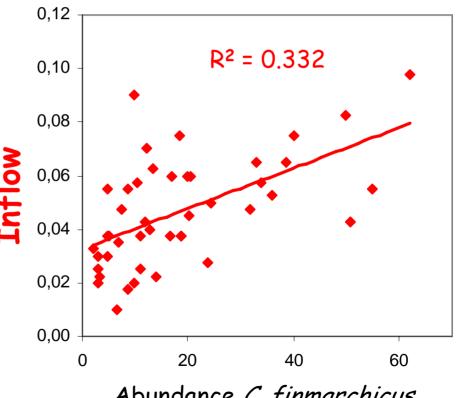
Modelled inflow of deep water from the Norwegian Sea into the North Sea during winter and

observed bottom temperature of the Norwegian Trench



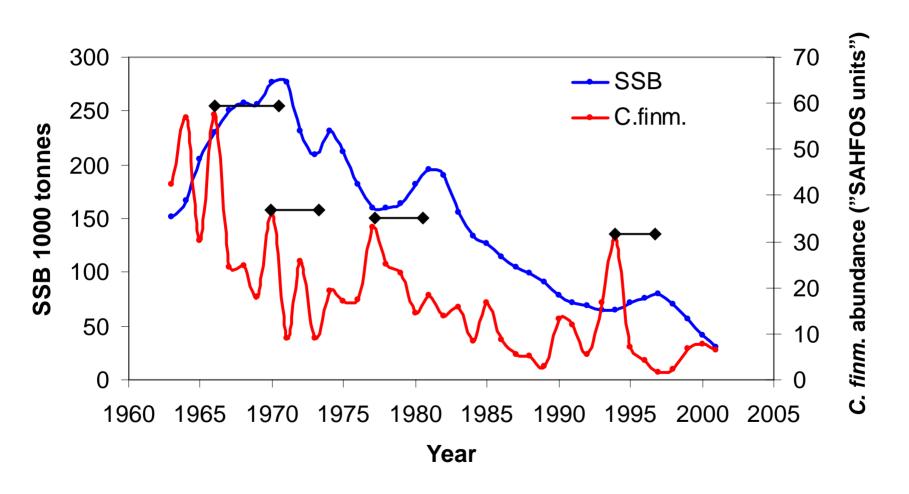
Observed abundance of *C. finmarchicus* in Northern North Sea during spring/summer and

modelled inflow of deep water from the Norwegian Sea into the North Sea during winter

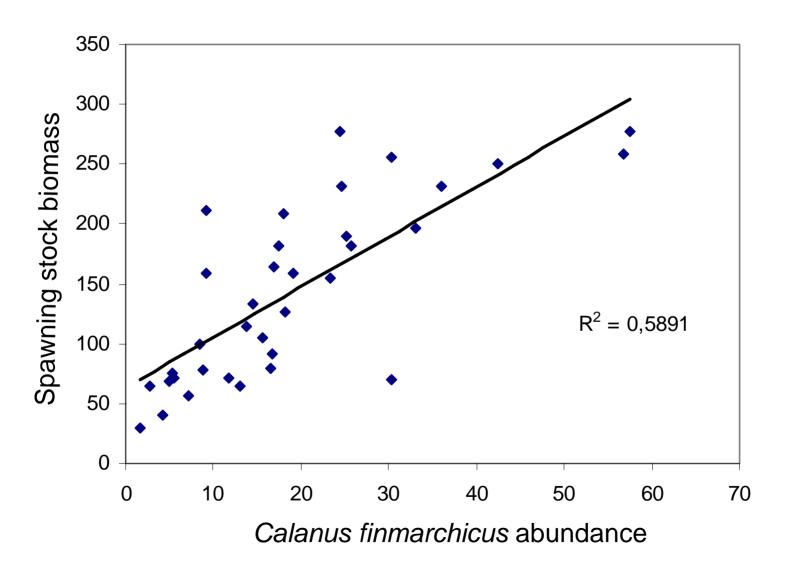


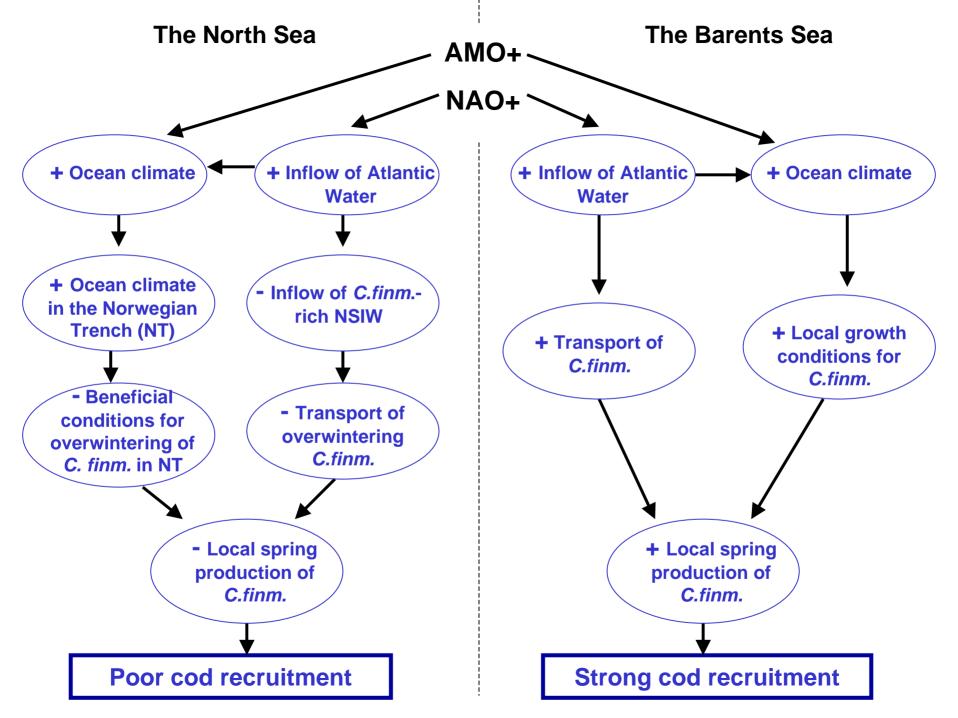
Abundance C. finmarchicus

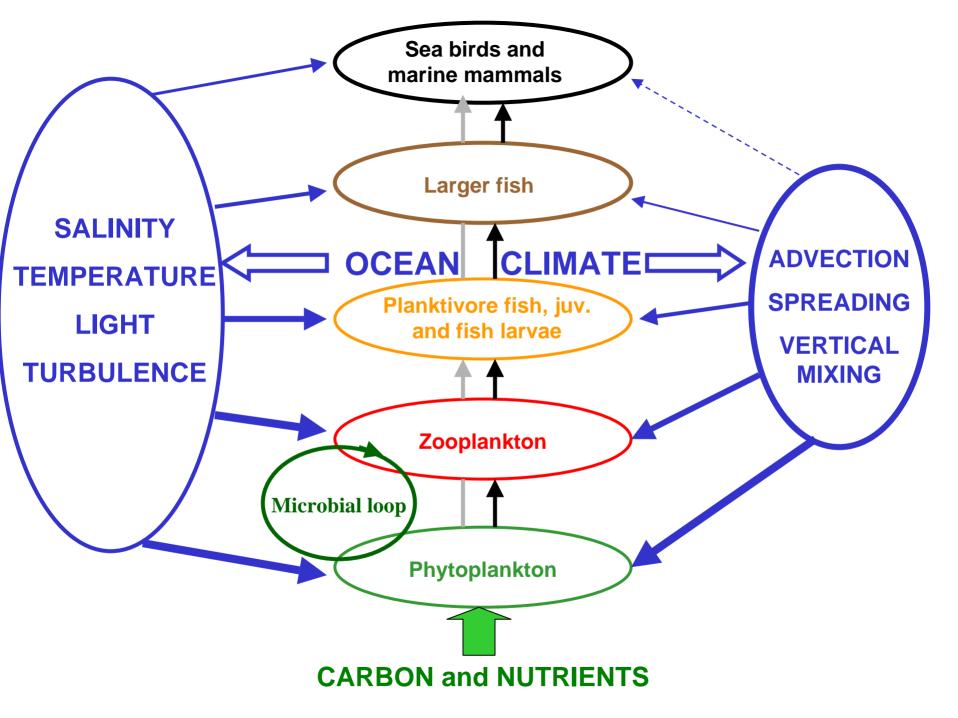
North Sea cod spawning-stock biomass (SSB) and spring/summer abundance of *C. finmarchicus*

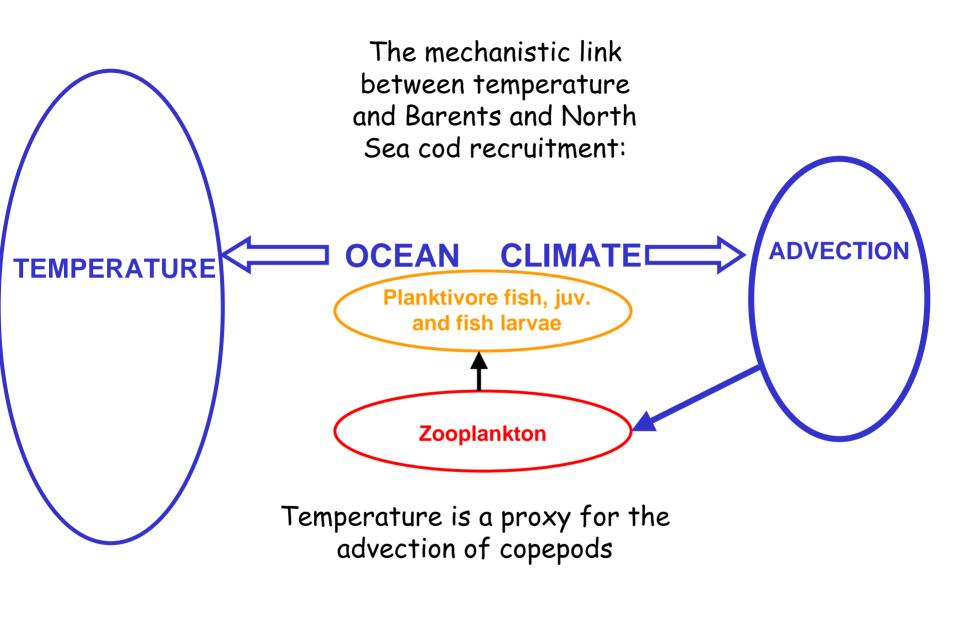


Abundance of *C. finmarchicus* in the northern North Sea (SAHFOS data) vs. the SSB of North Sea cod 4 years later



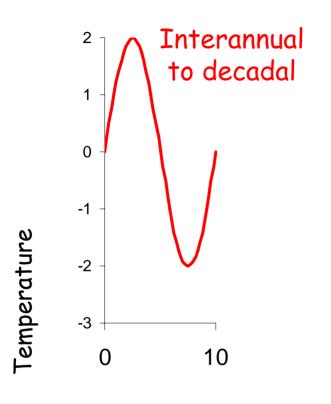








Climate effects on marine ecosystems vary with the periodicity

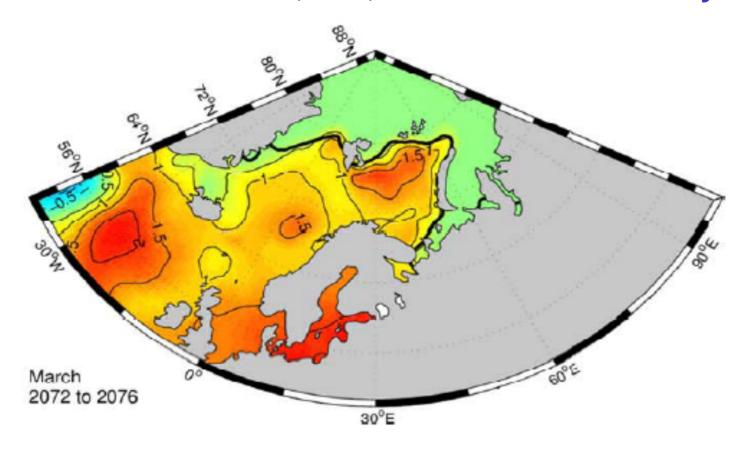


- Local production on lower trophic levels
- Fish recruitment and year-class strength

- Habitat extents of populations
- Production on higher trophic levels

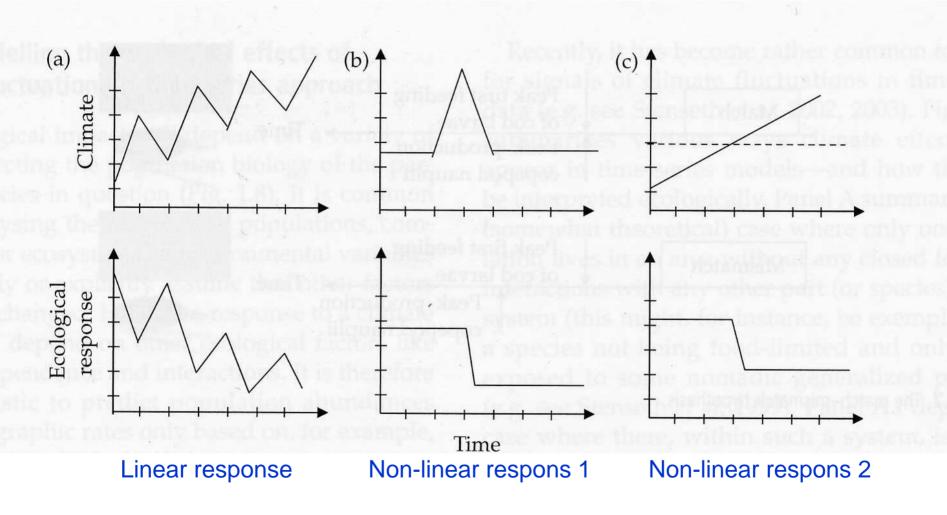


Predicted increase of sea temperature in the northeastern North Atlantic is 1,0 –2,0 °C over the next 70 years





Ecosystem responses to climate change



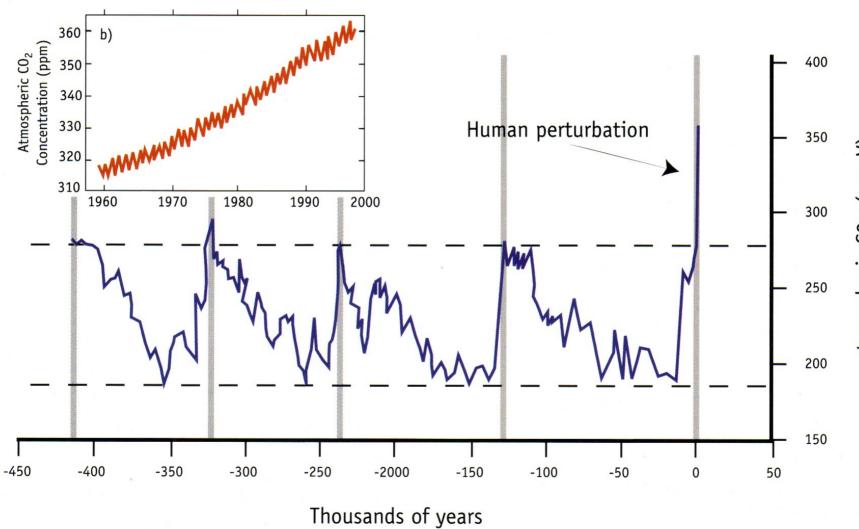
Ottersen *et al.* (2004)

Conclusions

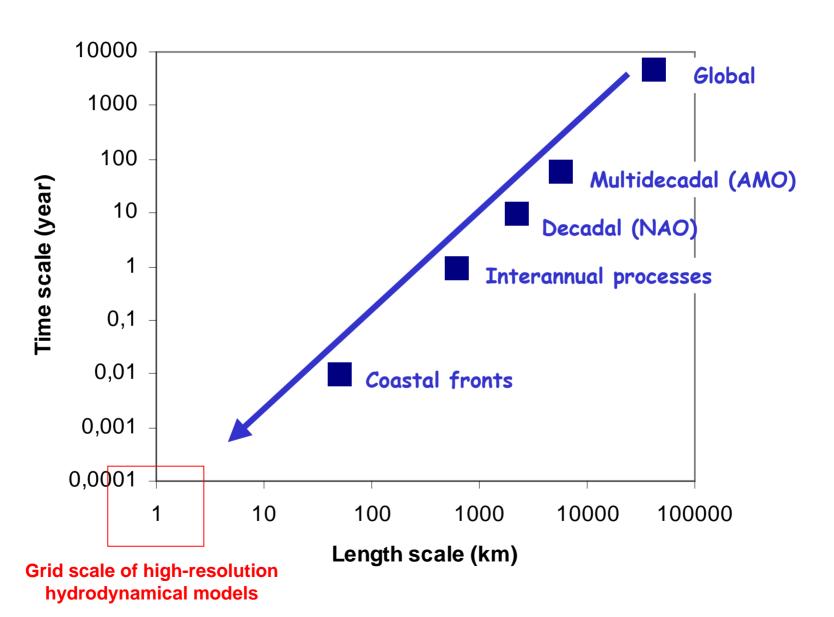
- Climate variables influence marine population directly and indirectly through the food web.
- The response of marine ecosystems to climate signals varies with the periodicity of the climate signal.
- The resilience of fish stocks to fishing pressure varies with the productivity in the ecosystem which in turn varies the climate forcing.
- The major fraction of the warming in the North Atlantic and in the Arctic after 1970 is probably caused by natural multidecadal variability.
 - if so, the warming is likely to decrease over the next decades, or even a cooling might happen.
- The responses of North Atlantic and Arctic marine ecosystems to AMO during the 20th century can be used to predict the effects of the climate change to come during 21th century.

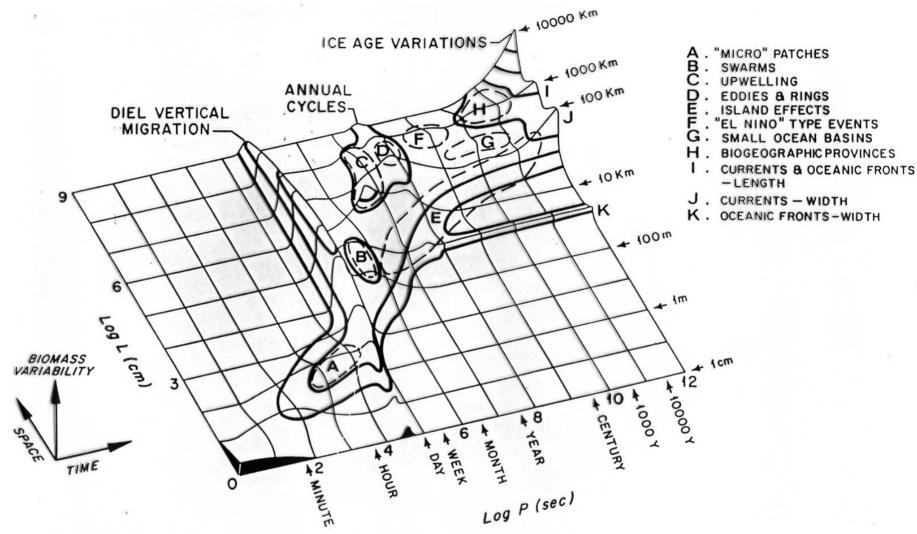






Spatio-temporal scales the ocean physics





Haury et al. 1978